SECTION OF MATHEMATICS, PHYSICS, AND INFORMATICS

THE EFFECT OF USING STEEL FIBERS IN THE CONCRETE OF CFT, SRC AND SRC COMPOSITE COLUMNS ENCLOSED WITH FRP COATING AND COMPARING THEM AGAINST CYCLIC LOADS

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Abstract

The use of composite columns is increasing due to the combination of concrete and steel in many structural systems around the world. Composite columns not only have many advantages in construction, but also improve the mechanical properties of structural members compared to concrete and steel members alone. These include increasing the chamber, increasing the shear strength and thus increasing the efficiency of the members. Also, the use of composite columns reduces the final cost of building the structure. In this research, three special types of CFT, SRC, and SRC columns reinforced with fiber reinforced concrete with FRP coating were discussed and with the help of ABAQUS finite element software, these columns were modeled and subjected to cyclic loading, and energy absorption diagrams and Their hysteresis is compared with each other. The advantages and disadvantages are identified and finally how these structures help to reduce the final cost is investigated and it was also determined that the reinforced columns with the help of FRP show better behavior.

Keywords: Steel fiber, CFT columns, SRC columns, Abaqus, manufacturing costs.

1- Introduction:

The use of composite columns is increasing due to the proper cooperation of concrete and steel in many structural systems around the world. Composite columns not only have many advantages in construction but also significantly improve the mechanical properties of structural members compared to reinforced concrete and steel members alone. These include increased enclosure, increased shear strength and thus increased member efficiency. Composite columns are made with different sections, so they have structural diversity. Composite columns are divided into the following four groups in terms of location of concrete, steel and FRP3

1. Steel pipes filled with CFST concrete
2. FRP pipes filled with concrete with or without CFFT internal reinforcement
3.steel sections buried in concrete or reinforced concrete steel sections SRC
4. DSTC double layer steel columns

Chen and Lin[1] in their analytical research that uses different steel cross-section shapes and designs Reinforcement networking was performed, investigating the confinement factors for high-confined concrete parts and partially confined concrete, and also Mirza and Scrabek, using their research, showed that these parabolic areas can be simplified and A rectangular shape was observed in which case the concrete with high confinement is located along the life of the steel section up to half the width of the steel section wings and the concrete continues with a partial confinement of half the width of the steel section wings along the section life to the center line of longitudinal reinforcements. Unenclosed concrete remains as external parts.

1-1- Steel pipes filled with CFST concrete

Steel columns filled with concrete are used in low-rise structures in non-seismic and iso-seismic areas, and are used as columns and beams in wind and non-wind frame structures. These columns consist of four welded metal plates in the form of square or rectangular sections or metal tubes in the form of circular sections, which have been used as columns in some of the tallest buildings in the world, including the Taipei 101 skyscraper. 106 floors in Taiwan. These types of sections have significant advantages over equivalent steel and reinforced concrete members. Internal concrete increases the stability of the metal pipe. CFT columns can improve structural characteristics against earthquakes and can create uniform seismic resistance in two perpendicular directions. Its components show composite behavior. That is, concrete and steel elements work in a combined way. The role of the concrete core in the composite column is not only to deal with the compressive forces but also to prevent the buckling of the metal members. The cross section of metal columns filled with concrete is shown in Figure 1-1.

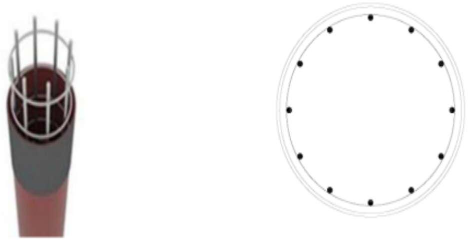


Figure 1 1 column section CFST

1-2- FRP pipes filled with concrete with or without CFFT internal reinforcement

CFFT consists of an FRP tube filled with reinforced or non-reinforced concrete. The composite pipe in CFFT consists of several layers of FRP whose fibers are placed and made at specific angles to provide vertical and shear stiffness and environmental resistance required for encapsulation. The cross-section of FRP pipes filled with concrete is shown in Figure 1-2.

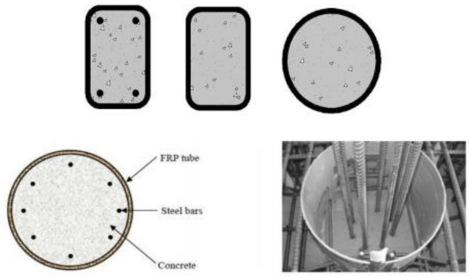


Figure 1 2 CFFT column section

1-3- steel sections buried in concrete or reinforced concrete steel sections SRC

SRC refers to sections that are buried in concrete. This type of hybrid columns are effective and active structural members that are used in short and long structures around the world. Many merits such as quick installation of steel sections before concrete molding, increased strength and increased ductility can be stated for this category of columns. Also, they control the displacement of the structure against earthquakes, the foundation of bridges that are exposed to high traffic, supporting columns.

The cross section of these columns is shown in Figure 1-3.

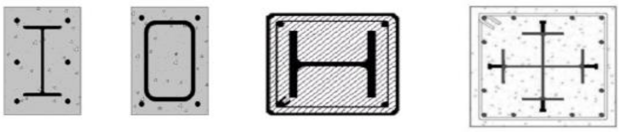


Figure 1 3 Cross section of SRC column

1-4- DSTC double layer steel columns

The idea of two-layer columns was first proposed by " K.M.YeeDrH.Shakir-KhalilR.Taylor " in 1982[2]. This column model consists of two concentric steel layers with concrete enclosed between the two layers. In this field, other studies were conducted by researchers such as "Wei" in 1945, "Hen" in 1945, "Yagishita" in 2000, "Zao" in 2002 and "Tao" in 2003. In addition to the advantages of composite columns, these columns also had disadvantages, for example, due to the steel on the outer surface of the column, the issue of protection against fire and corrosion was raised, and special measures were required. These columns consist of a steel tube and an FRP layer in the outer membrane, which is filled with concrete between the two tubes. In the term, these columns are called tubular columns with two layers of DSTC coating, which are used as columns or beams. The empty space in the columns has no effect on the bending stiffness of the section and helps the passage of utility pipes as a duct. Buckling is delayed or completely stopped due to confinement in the inner steel tube. When the inner tube buckles or yields, the concrete in the DSTC column is placed in an unconfined position, this is before the rupture of the FRP coating in the outer membrane, after which the untimely failure of the column occurs due to the rupture of the FRP fibers. This shows that the thickness of the inner tube and the thickness of the outer FRP tube can affect the strength and flexibility of the DSTC column. In order to reduce the consumption of materials and increase the buckling resistance, it is possible to choose a corrugated inner tube. The cross-section of this type of hybrid columns can be seen in Figure 1-4

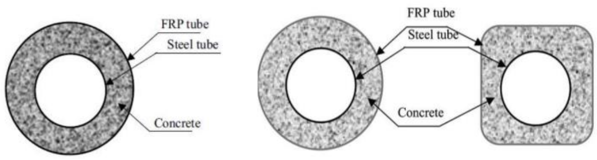


Figure 1 4 Cross section of DSTC column

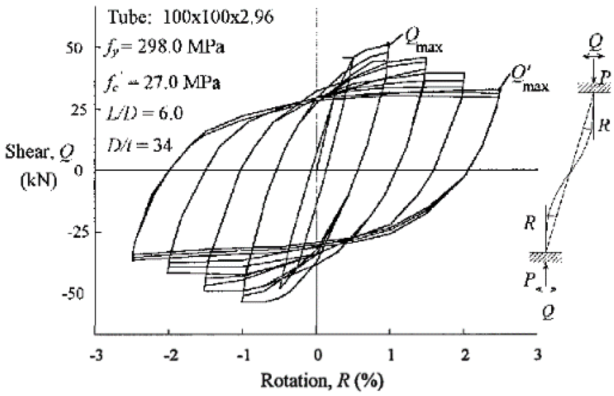
It should be noted that application of the Meta-heuristic Algorithms, and also the other applicable methods in optimization have been mentioned in many of the research works. The algorithms could minimize or maximize the objective function of a problem[13]. Meta-heuristic algorithms have been used for optimization in various fields such as composite columns, concrete slabs [14], [15], [16], [17], modification of ground motions [18], solve construction site layout problems (CSLP)[19] and etc.

2- Background review:

One of the basic problems of FPR composites is the early separation of FRP sheets before the fibers reach the final strain and tear. In 1999, Blaschko and Zilch proposed the FRP in concrete slits method instead of the conventional FRP installation method on the surface, EBR1, to solve this problem. More studies on this method were done in 2000 by De Lorenzis and from that date onward this method became NSM2. where the FRP sheets were installed on the grooves, their observations showed that this method can significantly delay the early separation of the FRP coating and in some cases it can completely solve the separation problem. The following year, in 2013, Mostufinejad and Shamli [3] presented a completed method in which FRP sheets were installed inside the grooves instead of being installed on the grooves; This method was named EBRIG 9 In continuation of the studies conducted on this method, in 2015, Moshiri et al. investigated the effects of this method in the case where the fiber direction is parallel to the column axis, on increasing the compressive capacity of the column. The results showed that the NSM method and the use of FRP strips are not suitable for increasing the compressive capacity due to the sensitivity of this method to placing the fiber direction completely parallel to the column axis. While the EBRIG and EBROG methods had significant effects on increasing the compressive capacity, the FRP coil increases the compressive strength and has no effect on the bending strength, in other words, the FRP coil cannot significantly improve the axial and bending interaction capacity. Therefore, when the column needs to be strengthened, the D/C ratio (Demand/Capacity) is not sufficiently satisfied by increasing the compressive strength resulting from confinement. On the other hand, research shows that by increasing the bending moment, the efficiency of the FRP composite wrap is increased. annulars decrease in the increase of compressive capacity. As mentioned earlier, to solve this problem, researchers have used FRP sheets in the longitudinal direction The main problem of using FPR sheets in the longitudinal direction is their early separation from the surface Concrete is under compressive force. With the presented strengthening method, it is expected to solve this problem.

3- Methodology and approach:

Composite box column, filled with concrete (CFT) is increasingly used as a column or column beam in wind-braced structures or flexural frames. Using cold rolled circular or rectangular square sections in various buildings with prestressed or cast-in-situ concrete has become common all over the world. To be resistant to seismic forces, multi-storied buildings are wind-sealed and bending frames are used. Boxy columns filled with concrete are made of welded plates and tubes are used in tall buildings of the world with circular columns. In general, in Japan, this method is commonly used for bridge columns. Concrete-filled members in structures have good results with balanced sections of steel, reinforced concrete, or steel reinforced with concrete. CFTs provide excellent uniformity when constructed of composite steel-concrete frames including I-sections in square, rectangular, or circular main beams that are fully or partially supported by the frames or their connections. And high resistance against earthquakes in the vertical direction and good fit for resistance against one-way bending along with axial load. For the seismic design of CFTs in the bending-resistant part of the frames, the ratio (resistance to weight) is very high, and due to the confinement of concrete and continuous wind wrapping, strip boxes with high resistance (resistance to weight) of the box columns cause a delay in buckling. It becomes local in it, the corrected depreciation behavior is evident in comparison with normal steel frames, and the increase in formability and hardness of steel is placed outside the environment, which effectively acts in bending resistance as well as tension and axial pressure. while concrete forms as a core will help to resist compressive loads. For the boxy column filled with concrete under bending and shear, a large part of the hardness and strength is distributed by the steel around the cross section, which has the greatest effect on all these materials. CFT beams, when loaded in uniform bending, show excellent early ductility to failure. Beams with normal resistance capacity of materials and relatively strong box usually fail in a combination of steel yielding in tension, buckling of steel box in compression, corrosion of concrete in compression and finally tearing of box steel in tension. A limited number of tests have been performed on CFTs under pure bending load as a column. These tests were carried out by Brij on CFT rectangular square columns with one-way and two-way bending so that the core concrete can withstand only 7.5% of the members' capacity in pure bending. Lowe and Kennedy reported a 10-30% increase in strength of rectangular square boxes, and they demonstrated the formability of the failure mode. Few tests have been performed under torsional loading. In tests limited to columns under uniform torsional load, it was well done. The metal tube alone behaves relatively well against torsion. Torsional failure in CFT columns is not specific and sudden, but is characterized by a large increase in torsional rotation during a relatively constant anchor. Failure occurs due to a combination of spiral cracks in concrete and tensile yielding of steel. The effect of axial load on torsion is the most damaging to the column, although if the axial load increases to 1.5 times the axial limit load, a small increase in the torsional resistance of the member is created. The initial torsional stiffness of CFT columns usually originates from the metal tube. Previous tests conducted by Four Long show that creep has an effect on the long-term behavior of CFT columns, although this brief effect is overcome by the confining metal box. "Naki" has announced the coefficients obtained from creep (ratio of final strain to initial elastic strain) in about half of the value obtained from flat concrete. Furlong found that slow loading can reduce strength gain by 15% and that shrinkage in columns causes rebinding. However, its effect on the final behavior of CFT columns has been realized. The level of residual stress in metal boxes depends a lot on the factory stages and the shape of the section. For the general purpose of cold-formed sections and welded stages, welded cold-formed boxes have a higher capacity than seamless boxes for residual stress, and rectangular cold-formed square boxes have more residual stress than circular sections. Longitudinal residual stress occurs in cold metal boxes of the given form. In different thicknesses, it effectively rounds the strain hardness curve. [16-59]



Columns filled with concrete under combined axial and off-axis forces and bending typically show a complete hysterine curve with high energy absorption. Axial load can affect shear and bending capacity.

The main behavior of the case observed in the experiments is explained experimentally below:

 Elastic loading: CFT loading in such a way that the stiffness of the overturning load is equivalent to the stiffness of a primary loaded member, so the elastic stiffness will decrease a bit due to concrete corrosion before reaching the stability value.

 Zone of reduction of linear behavior: The size of the approximate zone of linear behavior in a CFT decreases with cyclic loading, mainly due to local buckling and corrosion of the concrete or as much as the decrease in the size of the elastic zone depends on the steel of the material. At the end of the region, the linear behavior stabilizes at a non-zero value.

 Reduction of resistance: the maximum resistance obtained is equal to each reduction of hysteresis cycle in the stages of the cycle; It basically depends on the local buckling of the steel box and the damage to the concrete. This reduction of resistance is the lowest possible value for CFTs with thick walls and it decreases with the increase of concrete amount.

 Bauschinger effects: The Bauschinger effect is shown as a type in the stress level in the steel wall in Figure 1-3 with the release of the resulting CFT stress level.

 Gradual reduction of hardness: during the reciprocation of loading, the hardness of a CFT will gradually decrease from its elastic value, due to geometry and non-linear materials, in each half cycle of loading, according to the evidence in the figure, the hardness will decrease.

 Bounded hardness: CFT has a bounded range of hardness (nearly zero hardness) which can be clearly seen in the last two cycles of the hysteresis loop in Figure 2-4. The inferred constrained stiffness is evident for the stability of the strip wall of the column even after local buckling.

In many existing reinforced concrete columns that are not provided with sufficient seismic details or transverse reinforcements, three cases of failure under seismic loads are seen.

The first and most critical column failure mode is shear failure. When the tensile strength of concrete is reached and diagonal cracks appear, shell concrete starts to fall. After that, the tearing and opening of the transverse reinforcements and as a result the buckling of the longitudinal reinforcements takes place. The above process leads to the disintegration of the core concrete, and the sudden and brittle failure of the column. Figure 5-1 a.

The second column failure mode is the failure of the plastic joint area. After the appearance of bending cracks, crushing and spilling of shell concrete, with buckling of longitudinal reinforcements or compressive failure of core concrete, failure of the plastic joint area begins Figure 5-1 b. This failure mode is more favorable than shear failure due to large inelastic bending deformations.

The third mode is the detachment of the longitudinal reinforcement patch, which is usually located in the area of the two ends of the column with the highest anchor demand. The bending strength of the column is maintained only when the detachment of the reinforcement patch is prevented. Detachment of the reinforcement patch occurs with the initiation of vertical cracks, further expansion of concrete and pouring of shell concrete, and leads to a rapid drop in the bending capacity of the column before causing large inelastic deformations and thus reducing the energy absorption capacity Figure 1-5 c.

Column failure modes under seismic loads
a) shear failure, b) plastic joint failure, c) reinforcement patch separation

As mentioned, FRP composite covers can be used around the column to strengthen the column. The most common application of these coatings is to place the composite fibers completely or vertically in the direction perpendicular to the longitudinal axis of the column or in the circular direction (peripheral direction). In this case, due to the lateral expansion of the column, annular tensile stresses are created in the composite. As a result, the FRP composite increases the strength and deformation capacity of the column by applying the enclosing lateral pressure, prevents the separation of the reinforcements at the patched place, and prevents the buckling of the longitudinal reinforcements. Also, some defects in reinforced concrete columns, such as the large distance of transverse reinforcements, can be compensated by wrapping the column in a ring composite cover. The use of spirals in column reinforcement has been well studied by various researchers.

But it should be noted that FRP composite with axial diagonal fibers or composite with multidirectional fibers can also be used; which, in addition to increasing the column's resistance, significantly increases its deformation capacity.

If a composite with axial fibers is used to strengthen the column, this composite increases the capacity of the column by bearing part of the compressive stress on the column. Considering that many existing columns are affected by the combination of axial load and bending anchor, the use of FRP composite with axial fibers seems to be a suitable method to strengthen the column; Because with the presence of bending anchor in the column, the effect of annular composite is reduced.

Modeling:

Column modeling individually

In this research modeling and research, the Standard / Explicit Model module of ABAQUS [4] 6.14.2 finite element software has been used. Load-displacement diagrams at the site of load application have been studied and analyzed

Behavioral characteristics of models

The most important properties of steel are high ductility and durability, high yield strength and tensile strength and good thermal conductivity. In addition, the properties of stainless steels have anti-corrosion properties. For steels, there are several ways to measure properties. For example, tensile strength, flexibility and stiffness can be measured by tensile strength tests. Hardness is measured by impact testing and hardness is measured by measuring the penetration resistance of the hard sink. Tensile test is a test to determine the reaction of steel to the application of force. The answers are expressed by the relationship between stress and strain. By measuring the ratio of stress to strain, the elasticity of the material can also be measured. The ratio of stress to strain in the elastic range of metals is called the Young's modulus. The elastic modulus of steels is in the range of 190-210 gigapascals, which is about three times the elastic modulus of aluminum. In modeling, three types of steel are used for reinforcements, braces and dampers with the specifications mentioned in the following tables.

Table 1

Fiber concrete plastic damage specifications

Dilation Angel	Eccentricity	f_{b0}/f_{c0}	K	Viscosity Parameter
30.5	0.1	1.16	0.666	0.001

Table 2

Behavioral curves of concrete in the nonlinear compressive zone

Stress (MPa)	*Stress* (MPa)	*Inelastic Strain*	*Stress* (MPa)	*Inelastic Strain*	*Stress* (MPa)
6.293636	12.342636	0.003940	9.147820	0.006152	5.994836
7.347664	12.185450	0.004051	9.009165	0.026190	5.836360
8.301422	12.026420	0.004088	8.849530	0.006373	5.678930
9.087816	11.866984	0.004272	8.692798	0.006484	5.518661
9.821314	11.707856	0.024382	8.534394	0.006595	5.359877
10.457989	11.549380	0.004493	8.375261	0.006705	5.200445
10.999736	11.391050	0.004604	8.218075	0.006816	5.041790
11.443924	11.230355	0.004714	8.059045	0.006927	4.882155
11.826071	11.072160	0.004825	7.899609	0.007037	4.725423
12.138594	10.913505	0.004935	7.740481	0.007075	4.567019
12.398636	10.753870	0.005046	7.582005	0.007258	4.407886
12.596942	10.597138	0.005157	7.424575	0.007369	4.250700
12.746583	10.438734	0.005267	7.264306	0.007480	4.091670
12.853922	10.279601	0.005378	7.105522	0.007590	3.932234
12.923601	10.122415	0.005489	6.946749	0.007628	3.773106
12.964048	9.963385	0.005599	6.780895	0.007811	3.614630
12.976540	9.803949	0.005710	6.627200	0.007922	3.457200
12.816905	9.644821	0.005820	6.472430	0.008033	3.296931
12.660173	9.486345	0.005931	6.313400		
12.501769	9.326015	0.006042	6.153964		

CFT column modeling

The element used in concrete modeling in Abaqus software is the next three elements and 8 homogeneous C3D8R nodes. This element does not have special conditions and is not designed for concrete, but is used in all models whose material behavior is complex.

Each of the desired models includes 2 parts.

Steel can 50 * 4 shelh / extrusion

Concrete with dimensions of 496 * 496 of shel / extrusion type

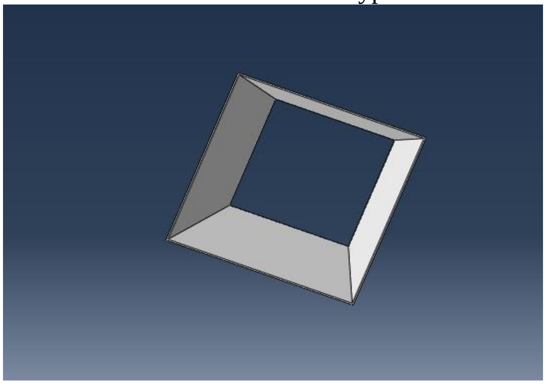


Fig 1: Cross section

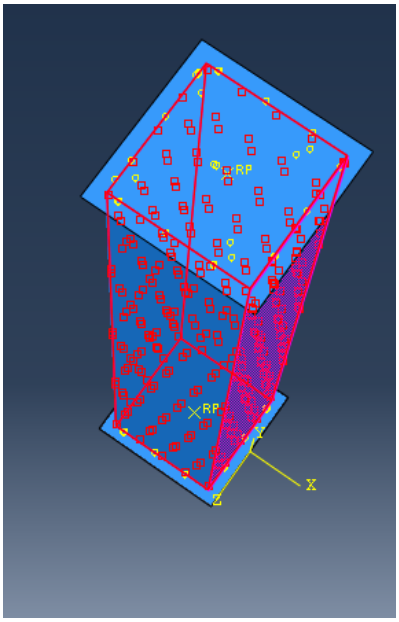


Fig 2: boundary condition

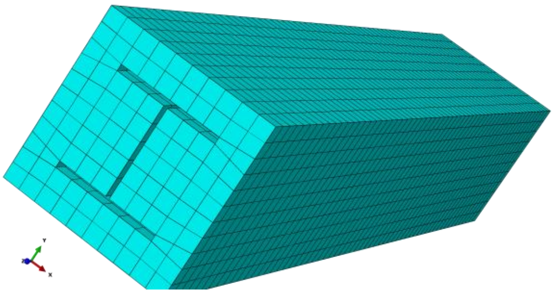


Fig 3: Src columns

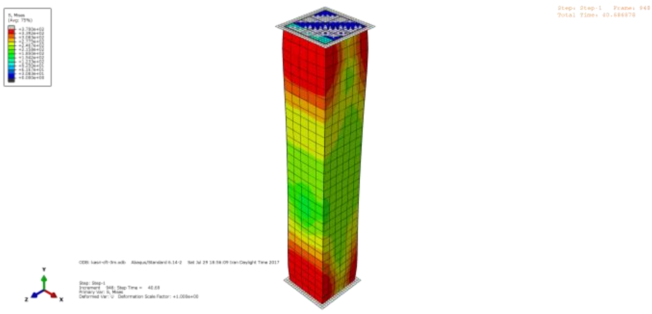


Fig 4: Von mises cft

As can be seen, von Mises stresses, which are one of the rupture criteria, are shown in these figures for the CFT column. The red dots indicate the points with the most stress. And the foot of the columns has more stress than the other points.

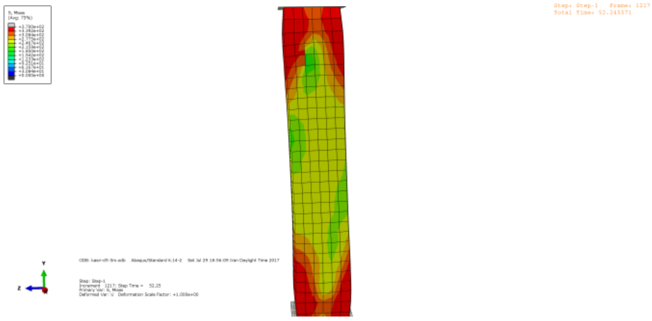


Fig 5: Von mises SRC

Advantages of steel-concrete composite column

The optimal location of the steel section

In CFT columns, due to the placement of the steel wall around the cross section just where the flexural and tensile stresses are most effective, it causes a significant increase in the stiffness and strength of the cross section. In SRC columns, their location is a factor in the rapid installation of the column.

High flexural strength at beam-to-column connection in SRC composite columns

Because the column and beam in this type of composite column are separated by reinforced concrete, the rotational stiffness increases due to the load transfer between the beam and concrete at the connection spring. Also, the tolerable flexural strength of the joint has a higher capacity than the original (unreinforced) steel joint.

Delay in local buckling

In composite sections, the steel column (compact, non-compressed) becomes more stiff due to contact with the hardened concrete, and buckling is delayed or does not occur. Therefore, buckling will be delayed as long as the contact between concrete and steel is reduced, such as cracking of concrete or separation of concrete and steel. However, in CFT columns, the concrete will remain in contact with the concrete wall as the concrete cracks to prevent over-expansion of the concrete wall. Therefore, the concrete core transmits lateral buckling modes to the outside, so thinner steel sections are used to ensure that the yield strength reaches the wall before buckling occurs.

High confinement in concrete

Steel sections increase the enclosure in the concrete core and consequently increase the strength and ductility in the concrete. Due to the cross-sectional shape and the created ring tension or belt tension, the circular sections of the CFT (CCFT) columns form more confinement than the rectangular sections of the CFT (RCFT) and SRC sections.

Save on construction costs

In CFT, the steel tube plays the role of a durable formwork for the concrete, which reduces human and material costs. CFT construction speed is much faster, especially in medium to high-rise buildings. The cost of the members themselves is much lower than that of a steel structure, with the cost of CFT almost equal to the cost of reinforced concrete members. Also, compared to steel flexural frame, in non-braced CFT frame, the saving of steel increases with increasing classes. Relatively simple connection details of the beam to the can column can be used. This reduces costs and simplifies design.

With high-strength concrete, CFTs are stronger per square foot than conventional reinforced concrete columns. Where high strength is desired, a smaller column size can be designed to increase the useful space of the building. A smaller, lighter skeleton rests on the foundation. Which will again reduce costs.

Fire proof

In sections buried in concrete, concrete acts as a steel cross-section protector against fire.

Conclusion:

After modeling SRC and CFT composite columns in Abaqus finite element software and loading them, the following results have been obtained.

1- Considering the displacement of the target caused by the lateral load pattern, it can be seen that the frame with SRC columns reinforced with FRP performed better than CFT and SRC columns.

2- According to the graphs obtained from the non-linear dynamic analysis, which shows the maximum displacement of the roof and the base cut, it can be concluded that the displacement of the structure and the base cut when reinforced SRC sections are used is better than the case of using CFT and SRC sections. Also, the performance of the structure when SRC sections are used is better than the performance of the structure with CFT sections for columns.

3- Energy absorption in columns reinforced with FRP is 83200 and in SRC columns is 74500 and in CFT columns is 52610 kN/mm, which indicates the better performance of enclosed columns.

4- The stiffness of the structure in CFT columns is 30.4 and in SRC columns it increases to 50.2 and after strengthening them it reaches 57.3 kN/mm which again shows their better performance.

5- The ductility of the structure has been significantly improved by using FRP coatings and its amount has reached from 96.4 to 2.5.

6- By using FRP coverings, yield points and yield elements are reduced and the structure can withstand more force and shows better behavior against earthquakes.

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PRINCIPLES OF CONSTRACTION A CONTROL AND REGULATION SYSTEM FOR A TECHNOLOGICAL COMPLEX, INCLUDING A VACUUM BLOCK

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Abstract

The article proposes conceptual principles for constructing an automated control system for the atmospheric-vacuum complex of a primary oil refining unit. The developed adaptive control system for the complex under study is presented in the form of a hierarchical structure, at the upper level of which the optimal operating parameters for the technological process are calculated, and at the lower level, mainly, the optimal regulation of technological parameters in the main apparatuses of the complex is carried out, ensuring the oil fractions production with the required values of quality indicators.

Keywords: distillation column, technological complex, control system, target product, regulation system, optimal control.

There are a considerable number of scientific publications devoted to the development of mathematical models, methods and control algorithms, as well as the construction of control systems for the main technological apparatuses of oil refinery and petrochemical plants [1÷5]. Most of these works took into account the deterministic nature of the technological processes occurring in these apparatuses.

Based on a complex of probabilistic-mathematical models that take into account the random nature of the input flows for a given technological object, the article proposes the principles for developing an optimal automated control system for a technological complex (atmospheric and vacuum blocks), which is a system with a two-level hierarchical structure that operates in dialog mode. The functional structure of the two-level control system for the considered technological unit of the investigated installation is shown in Figure 1.

At the upper level of the proposed control system, the optimal operating modes are determined for any values of the quantitative and qualitative indicators of crude oil entering the inlet of the electric desalination installation, Atmospheric vacuum tube type unit, which ensures the production of light oil fractions in distillation columns K-1, K-2, K-10, meeting the requirements of the standard for the depth of processing and the quality of oil fractions.

The optimization criterion chosen at this level is achieved with the help of the mathematical models constructed set of a deterministic and probabilistic nature, as well as an optimization algorithm based on the decomposition principle. In the case under consideration, depending on the amount and type of crude oil received for processing, the technical and economic indicators of the primary oil refining technological process are also calculated.